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U.S. EPA-Sponsored Epidemiological Studies of Health Effects Associated with the Treatment and Disposal of Wastewater and Sewage Sludge

by

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16. ABSTRACT

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U.S. EPA-SPONSORED EPIDEMIOLOGICAL STUDIES OF HEALTH EFFECTS ASSOCIATED WITH THE TREATMENT AND DISPOSAL OF WASTEWATER AND SEWAGE SLUDGE

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Summary

Since 1975 the U.S. Environmental Protection Agency has sponsored 11 epidemiological studies of the potential health effects associated with the treatment and disposal of sewage and sewage sludge. Three of these have been occupational exposure studies: One of sewage treatment plant employees, one of irrigation workers, and one of sludge composting workers. Four studies have involved populations living in the vicinity of activated sludge sewage treatment plants. Three studies concerned land application of wastewater for agricultural purposes, and the final study was of farm families utilizing digested sewage sludge on cropland. The design, results, interpretations, conclusions and costs of these studies are reviewed and discussed. Final analyses on two of the studies have not yet been completed. The preponderance of data was negative, but this has to be viewed with respect to the inherent problems in quantifying exposure of the involved populations and the absence of a clear end point for measuring an effect.

1. INTRODUCTION

Involvement of the United States Environmental Protection Agency (USEPA) with sewage-related epidemiological studies actually began as a result of the virus-in-drinking-water question. Virus transmission through drinking water has been, and continues to be, reported in outbreak situations (1). However, addressing the question of potential endemic low-level transmission of viruses through conventionally treated drinking water by epidemiological investigations would pose formidable problems in experimental design, the size of populations required and in the costs of conducting the studies. These problems are quite similar to the eight items of "Complexity and Errors" associated with wastewater and sludge epidemiological studies enumerated by Block (2). In 1965, J.L. Melnick (3) suggested that worthwhile information on the ability of small amounts of viruses in water to cause infection might be gathered through epidemiological studies of sewage workers. He further suggested that sub-clinical infection, rather than disease, be used as the end point response.

This idea was intriguing to investigators at the USEPA because it offered the hope of providing the necessary tools for resolving the controversy concerning viruses in drinking water. Studying sewage workers, a segment of the population assumed to have the highest exposure to waterborne viruses, would require smaller populations than would a study of drinking water consumers not having such occupational exposure. Using infection rather than disease as the dependent variable would eliminate

the uncertainty associated with the variety of symptoms produced by viruses while providing an objective measure of response. Infection could be determined either by isolation of the agents from clinical specimens or by serology, or both. If an epidemiological study could be designed and conducted using sewage workers, and if it produced other than negative data, this would establish that we had the methodology for evaluating relevant effects. The same methodology could then be applied to lesser exposed populations, e.g., drinking water treatment plant operators and the general population. It might then be possible to interpret negative effects in the lesser exposed population against a background of positive effects in the higher exposed populations.

Consequently, in 1975, the first sewage-related health effects study funded by USEPA was initiated under the Drinking Water Program. During the period between the Melnick suggestion and initiation of this study, the United States embarked on a extensive sewage treatment plant construction grants program which was brought about by the Federal Water Pollution Control Act (Clean Water Act). The construction program was designed to upgrade sewage facilities to secondary treatment with a goal of eliminating discharge of pollutants into navigable waters. As communities began dealing with the mechanics of implementing the construction programs, problems were encountered with siting of facilities, especially in densely populated urban areas, and concerns were raised about possible health effects from infectious aerosols produced at activated sludge treatment plants. Additionally, alternative treatment and disposal options for wastewater and sludge, directed to the beneficial use of these products for water and nutrient recycling, were encouraged. The primary focus of our health effects program then shifted to determining the potential adverse microbiological effects on populations living in the vicinity of activated sludge treatment plants, and to potential problems from the land application of wastewater and sludge.

Eventually, a total of 11 wastewater and sludge epidemiological studies were initiated and these are listed in Table I. These studies

Table I. USEPA-Sponsored Health Effects Studies
Wastewater and Sludge Treatment and Disposal

Category	Location	Reference
Occupational	Cincinnati, OH; Chicago IL; Memphis, TN	4-7
	Camden, NJ; Philadelphia PA; Washington, DC; Beltsville, MD	6,10,11
	Muskegon, MI	9
Populations Near Activated Sludge Plants	Tecumseh, MI	12
	Schaumburg, IL	13
	Tigard, OR	14
	Skokie, IL	15,16
Agricultural	Israel, retrospective	18,19
	Israel, prospective	20,21
	Lubbock, TX	22,23
	Columbus, OH	24

have been broadly categorized as occupational, agricultural, and studies of populations living near activated sludge treatment plants. Nine of the studies have been completed; the other two (Israel, prospective and Lubbock, TX) are scheduled for completion in the latter half of 1985. These studies will be described in more detail in the following chapters.

2. OCCUPATIONAL STUDIES

2.1. Sewage Treatment Plant and Maintenance Workers

The three occupational studies were all prospective in design. The first one was initiated in 1975 with the University of Cincinnati. The original intent was to compare infection rates in experienced and inexperienced sewer maintenance workers with a control group of highway workers. The study was subsequently broadened to include wastewater treatment plant employees and additional control groups in a total of three cities.

More than 500 workers in three cities (Cincinnati, Chicago, and Memphis) were recruited. The workers were divided into three broad categories: inexperienced and experienced wastewater exposed, and controls. A total of 336 workers remained with the study for the miminum 12-month requirement. Inexperienced workers were those just beginning employment. To be placed in the experienced category, a worker had to have been on the job for a minimum of two years. The control groups consisted of highway maintenance workers in Cincinnati, water treatment plant workers in Chicago, and utility workers in Memphis.

Health monitoring included maintenance of an illness diary, examination of employer absentee and illness records, annual multiphasic physical examinations and pathogen isolation attempts from stool specimens and throat swabs. Blood specimens were collected quarterly for subsequent serological analyses. A serologic survey was also conducted on the families of 82 wastewater and 41 control workers to determine possible associations with transmission of infectious agents to the home from the job. Limited aerosol and wastewater monitoring for indicators and pathogens was conducted in an attempt to refine exposure categorization.

The results of the illness analyses (4) indicated no significant difference in illness rates by worker group or by city, although gastrointestinal illness (GI) rates were two to four times higher in the inexperienced worker group. Combining the worker groups from the three cities did result in a statistically significant difference ($p = .004$) in gastrointestinal illness rates. Rates were higher in the inexperienced group and there was no difference between experienced workers and controls. A seasonal peak during April-June was observed. The GI illness rates for the inexperienced group were analyzed on the basis of time on the job and age of workers but no significant differences were detected.

There were no significant differences in virus or bacterial isolation rates among workers in the three cities although *Salmonellae* were isolated from sewage-exposed workers on six occasions. One isolate was from an inexperienced worker at the time employment began; one was from another worker after one year on the job, and the remaining four were from experienced sewage treatment plant workers. One *Shigella* isolate was obtained from a control worker. There was a significant difference in parasite isolation rates--three of 56 sewer maintenance workers (5.4%) had positive specimens compared with 10 of 69 (14.5%) highway workers (5). There was a suggestion that street cleaners may have a higher risk of parasitic infection.

The serologic analysis included a determination of immunoglobulin levels on the hypothesis that individuals exposed to low levels of micro-

organisms may develop higher levels of immunoglobulins. However, they were not found to be consistently higher in the sewage-exposed workers in any of the three cities. The virus serologic analysis involved comparing the geometric mean antibody titers, titer level changes (increases and decreases), and cumulative seroconversions among the worker groups in the three cities. A total of 594 comparisons were made, and based on chance alone, one might expect about 30 of these to be significant at the $p = .05$ level. Twenty-nine significant differences were found and they were distributed evenly among the exposed and control groups.

To improve the chances of detecting an effect, the inexperienced and control workers were further subdivided into low and high exposure categories on the basis of job observation and environmental monitoring. The virus serological results were then analyzed on a city-by-city and on a combined basis. A total of 510 comparisons were made and 23 of these were found significant. Nine out of 10 for the city-by-city comparison, and 10/13 for the combined analysis were in the direction indicating a sewage exposure effect and these were about equally divided between aerosol-exposed workers and sewage liquid/solids-exposed workers.

The major part of this study was completed in 1980. However, serum specimens collected during the study were archived. These sera were used for a subsequent survey of rotavirus, Norwalk agent and an algal (Prototheca wickerhamii) infection (6,7). Prototheca has been associated with wastewater environments. For Prototheca, sera from 110 participants were analyzed on the basis of antibody response, age, race, sex, geographic location, exposure group and economic status. For Norwalk agent and rotavirus, paired sera were analyzed from 48 workers who had reported gastrointestinal illness. No evidence was found to associate wastewater exposure with antibody levels to either rotavirus or Prototheca. However, although there was no excess of seroconversions to either rotavirus or Norwalk agent, inexperienced wastewater-exposed workers had higher levels of antibody to Norwalk agent than did the experienced and control workers. Also, those with high and medium aerosol exposure had higher titers than workers in the low aerosol exposure category.

To summarize this study, inexperienced workers reported higher rates of gastrointestinal symptoms than did experienced workers or controls. These rates could not be related to a specific agent or exposure. The symptoms were mild and transitory and did not result in time lost from work. Pathogen isolations did not indicate any increased risk from sewage exposure. The virus serological results are difficult to interpret, especially with regard to Norwalk agent, where the presence of antibody signifies susceptibility to this virus rather than protection. The investigation described above spanned a time frame of about nine years, at a cost to USEPA of about $1,500,000. (This, and all subsequent cost figures presented are in unadjusted dollars, and do not include cost-sharing by the performing institutions.)

One other aspect of this investigation was a mortality study of municipal wastewater treatment plant workers (6). This study was stimulated by a report that sewer workers in Denmark had a much higher rate of death from pancreatic cancer than expected (8). Analysis of 815 death certificates from former workers at the Metropolitan Sanitary District of Greater Chicago resulted in about twice as may leukemia deaths as expected (11 observed, 6 expected: $p = .04$). For cancer of the esophagus there was also about twice as many deaths as expected but this was not significant using Illinois vital statistics. There was also a significant difference ($p = .02$) for deaths due to pnuemonia--less than one-half as many deaths as expected were observed. The investigators concluded that

additional research was necessary.

2.2. Study of Spray Irrigation Workers

In 1978, a study of workers was begun at a land application system in Muskegon, MI where corn (maize) fields receive low-pressure spray irrigation of partially treated lagooned wastewater (9). The study included 35 spray irrigation workers and 41 county road commission controls. Three exposure categories were used: high-exposure to both wastewater and aerosols; intermediate-exposure to either wastewater or aerosols, and low--administrative and laboratory personnel with no direct exposure to wastewater or aerosols. Workers were seen monthly during the growing season from June through October, and they provided a history of the illnesses from the previous month, throat and rectal swabs for virus culture and serum specimens for serologic studies. Environmental samples included wastewater and air for virus and bacteria analyses. No differences in clinical illnesses were observed between the irrigation and the road workers. Poliovirus type 3, coxsackievirus B2 and echovirus 7 were isolated from wastewater influent to the aeration basins, but no viruses were isolated from influent to the irrigation rigs, or from air samples. Only one virus (coxsackievirus B5) was isolated from clinical specimens and that was from an asymptomatic control worker. There were no differences in antibody to hepatitis A or to Legionella between the wastewater workers and the controls. Antibody levels to polio, coxsackie and echoviruses did not differ between groups. However, six seasonal workers who were hired as nozzle cleaners had significantly higher levels of antibody to coxsackievirus B5, but seroconversions were not documented and there was no clinical illness. The investigators concluded that there was a very limited risk of infection among workers using partially treated wastewater for agricultural purposes. The study lasted about two years and cost approximately $178,000.

2.3. Compost Worker Study

Between 1979 and 1981, a prospective epidemiological study was conducted of workers at wastewater sludge composting facilities in four cities--Camden, NJ, Philadelphia, PA, Beltsville, MD and Washington, DC (10,11). A total of 388 workers from the four cities participated in some aspect of the study. There were three exposure categories: high--98 workers directly engaged in composting; intermediate--157 workers occasionally involved with composting or with job locations within 100 m of a composting operation, and low--133 workers not involved in compost activities and with job locations greater than 100 m from the sites. The clinical and serological evaluation included illness monitoring (30-day recall); physical examination and chest x-rays; nasal and throat cultures; pulmonary function tests; antibody testing to fungi, Legionella, histoplasma and endotoxin; immunochemical testing, and routine blood analyses. Environmental monitoring consisted of air sampling for Aspergillus fumigatus and other thermophilic fungi.

For the illness reports, more symptoms of burning eyes and skin irritation were reported among compost workers. Physical examination showed that more high and intermediate-exposed workers had acute or chronic inflammation of the eyes and nose, evidence of ear infection and skin conditions. However, the investigators indicated that these results should be interpreted with caution because of the relatively small number of workers involved, geographic differences in nasal disorders and because the intermediate-exposed workers had a similar or higher proportion of disorders than did the compost workers.

The prevalence of positive A. fumigatus cultures from the anterior nares and throat swabs was consistent with the exposure designations--70% from the high, 20% from the intermediate and 5% from the low categories. Pulmonary function tests showed that compost workers had a higher forced vital capacity on Friday evenings as compared to Monday morning. Compost workers had the highest IgG antibody levels against compost-derived endotoxin. No consistent increase in antibody to A. fumigatus was detected. There was no difference among exposure groups in antibody to Legionella pneumophila and antibodies to Histoplasma capsulatum were not detected. Immunochemical tests suggested that compost workers may experience a low-grade inflammatory response since they had elevated C3 and hemolytic complement levels. These results were consistent with the routine blood tests which showed higher white cell and eosinophile counts in compost workers. In summary, this study did show effects in the compost workers but they may be associated with the composting process itself through high dust levels and occurrence of A. fumigatus, rather than with the presence of the sludge component. The cost of this study was approximately $725,000.

3. POPULATIONS LIVING NEAR SEWAGE TREATMENT PLANTS

Four epidemiological studies of populations living in the vicinity of activated sludge sewage treatment plants were completed in 1978 and 1979. Two of these (Tecumseh, MI and Tigard, OR) were retrospective studies and the other two were prospective.

3.1. Tecumseh, MI

Tecumseh, Michigan was chosen as the site for this preliminary investigation because it was part of a comprehensive community health study conducted by the University of Michigan. The study population was divided into five concentric rings radiating outward in multiples of about 600 m from an activated sludge treatment plant (12). In 1965, the plant was converted from a trickling filter facility to activated sludge treatment. The study period was from 1965 to 1971. Average monthly sewage flow rates ranged from 0.64 to 1.18 MGD. Self-reported acute illnesses and symptoms from 4,889 participants during the seven-year period were grouped into total, respiratory, and gastrointestinal illness categories. Age-sex-distance-specific incidence and illness rates were analyzed using the minimum discrimination information statistic. Data on income and education were also used in the analysis.

The results indicated that there was a greater than expected occurrence of total respiratory and GI illnesses in those living within 600 m of the plant. However, this portion of the population also had lower income and education than the rest of the study group. The investigators suggested that high densities of lower socioeconomic families might be a more important factor in excess illness than would be proximity to a small wastewater treatment plant. Some excess illness (total, respiratory and GI) was also reported for those living within the 2,400 m concentric ring. These people had both higher incomes and education than any of the other groups and there was no known source of exposure for acute illnesses in this area.

This retrospective study was obviously inconclusive and was undertaken because of the availability of the data and the relatively small expense involved (about $21,000). Limitations on interpretation of these results include: the presence of a confounding demographically heterogeneous population, the lack of exposure and meteorologic data, and the relatively low volume of the exposure source. Differences by distance

were detected, but determining the causes of the differences was outside the scope of the project.

3.2. Schaumburg, IL

In this study, an opportunity was available to follow a community population before and after an activated sludge treatment plant went on line (13). The study period was from 1974 to 1976 and the John E. Egan plant became operational in December, 1975 with average daily flow rates of 10-15 MGD. The study design included a health survey of about 4,300 individuals (of a total population of about 100,000) living within 5 km of the plant. The residential area began 350 m from the plant. Clinical specimens from a subset of this population (226 individuals) living within 3.5 km of the plant were examined for bacteria, viruses, parasites, and viral antibodies in serum. Wind speed and direction, and relative humidity, were monitored. Large-volume aerosol samples and wastewater samples were examined for indicators and pathogens.

The results of the health survey indicated no change in asthma-hay fever symptoms, decreases in worm infections, and decreases in sore throats after the plant went into operation. Significant ($p < .01$) increases in the incidence of six diseases or symptoms (skin disease, chest pain, diarrhea, weakness, nausea, vomiting) were reported by those within 2 km of the plant. Furthermore, all showed a relationship with direction from the plant, i.e., increases were at the close distances in the north and south directions, the predominant downwind quadrants. However, the results for at least five of the six show considerable variability with distance before the plant went into operation or show significant decreases in those living more than 2 km from the plant. Nevertheless, one symptom, diarrhea, showed remarkable uniformity in reporting throughout the study population and increased from 4.1 to 7.6% in those living 0-2 km from the plant. This finding is also interesting in that the post-operational survey included a lower proportion of young children who would be more likely to experience diarrhea. These results must be considered in the context of the survey methodology used. Participants were asked on two occasions to report all acute diseases occurring in the family in the previous year and to list all symptoms occurring in the previous three months. The accuracy of surveys requiring that much recall is open to serious question even if the respondent is reporting only on himself. In addition, survey participants knew that the study involved possible health effects of the sewage treatment plant.

The study also included objective measures of infection--serology and isolation of pathogens from clinical specimens. Proteus, Pseudomonas and Salmonella were the only pathogen isolates from fecal samples. There was a significant decrease in Proteus isolations during the operational period and no significant differences in Pseudomonas and Salmonella isolations. Streptococcus and Staphylococcus isolations from throat swabs increased during the operational period. However, the increases were not related to the treatment plant as shown by regression analysis of the incidence pattern with distance and direction from the plant. There were no significant differences in isolation of parasites from fecal specimens. No viruses were found in throat swabs but 20 viruses were found in fecal samples. There was a significant increase in virus isolations during the operational period but the increase could not be related to plant exposure. Antibody tests for 31 enteric viruses yielded no serologic evidence of a wastewater plant effect. The results of the aerosol monitoring indicated that levels of microorganisms in the air in residential areas were indistinguishable from background concentrations.

The investigators concluded that sewage treatment aerosols from well-operated American plants do not appear to pose significant health hazards. They also indicated that there was insufficient evidence to determine if minor effects, such as gastrointestinal symptoms and skin disease, were associated with aerosol exposure. The cost of this investigation was about $484,000.

3.3. Tigard, OR

A retrospective study conducted in Oregon combined the rapidity and cost advantages of the Tecumseh study with the exposure categorization experience gained in the Schaumburg project. A new activated sludge treatment plant had been placed into operation in 1976 within 400 m of an elementary school and local public health officials expressed concern about possible health hazards. A preliminary study was performed to determine the types and numbers of microorganisms in air upwind and downwind from the treatment plant and to compare absenteeism rates, as a measure of possible health effects, at the affected school and control schools (14).

The study design involved collecting seven years of attendance data prior to initiation of plant operations and for two years afterwards. Data were collected for the exposed school (Durham) and for five control schools in the Tigard district. The plant had a design capacity of 20 MGD but averaged 9-13 MGD during the study period. There were two possible sources of exposure to the wastewater aerosols: from a surge basin located within 50 m of the school playground, and from an aeration basin about 400 m from the school building. The Durham Elementary School had six classrooms (one for each grade), open-window ventilation, and an enrollment in June, 1978 of 123 students. On-site measurements of wind speed and direction, temperature, humidity, solar radiation and cloud cover were made. Composite wastewater samples and large volume air samples were collected from the aeration and surge basins and examined for indicator and pathogenic microorganisms.

The absenteeism at the exposed school actually decreased during plant operation. These negative data must also be considered in the context of the results obtained from the environmental monitoring and exposure calculations. The aeration basins were found to be a much stronger source of microorganisms than the surge basin. The geometric mean aerosol concentrations at 30 to 50 m downwind of the aeration basin were 12 colonly forming units (cfu)/m^3 of total coliforms, 4.2 cfu/m^3 of fecal streptococci, 10 cfu/m^3 of mycobacteria, 1.5 plaque forming units (pfu)/m^3 of coliphage, and less than 0.0002 pfu/m^3 of enteroviruses. However, the exposure calculations based upon the meteorological observations indicated that the classroom area was steadily downwind of the aeration basin for only 10 days in the two operational years. In addition, because of rainfall, the playground may have been in use on only 40% of the days when it was steadily exposed to aerosols. The investigators concluded that the wastewater aerosols had no effect on infectious disease incidence as determined through absenteeism for this level of exposure. The cost of this study was about $63,000.

3.4. Skokie, IL

Probably the most thorough and the last of the treatment plant health effects studies was conducted by the University of Illinois near an activated sludge facility with an average daily flow of 290 MGD (15). A subset of the population living within a 1.6 km radius of the plant was studied for an eight-month period. A comprehensive health questionnaire

survey was conducted of 2,378 persons at the beginning of the study to gather demographic and historical health information on chronic and acute diseases. A subset of this population (724 persons) was included in a health watch program where health diaries were collected on family members every two weeks throughout the study period. Although the keeping of health diaries is not without problems, this procedure was felt to be a significant improvement over study designs relying on recall over a three-month or one-year period. A subset of this population (161 persons) provided a total of 1,298 throat and stool specimens for bacterial and viral analyses. In addition, 318 persons provided paired blood specimens obtained at the beginning and end of the study period and these were used to determine prevalence and incidence of infections with enteroviruses. It should be emphasized that the participants knew only that this was a study of the possible health effects of air pollution--they were not told of plans to correlate effects with the sewage treatment plant.

The project also included microbial aerosol monitoring and meteorological data collection (16). These data were used to generate personal exposure indices for each household. The environmental data were then integrated with the health data to determine any associations with the treatment plant source. Regression analyses were performed between total viable particle exposure indices and self-reported illness rates, pathogenic bacteria isolation rates, prevalence rates of virus antibody, and virus antibody titers. An attempt was also made to determine if various subpopulations were at risk to infection. Regression analyses between illness rates and exposure indices were run with reference to length of residence, age, smoking, presence of young children in the family, chronic respiratory disease, and chronic gastrointestinal problems. The results from all of these analyses were negative. No associations were found between any of the health factors and the treatment plant as an exposure source. However, the investigators cautioned that the overall conclusion that the plant had no obvious health effect on residents must be tempered by the small number of people who were exposed to the highest pollution levels. The cost of this study was about $643,000.

3.5. Summary of Wastewater Treatment Plant Aerosol Studies

All of these studies had good designs and were performed by competent investigators. The positive findings in Tecumseh were indeterminate--they correlated with socioeconomic status as well as with distance from the sewage treatment plant. In Schaumburg, higher gastrointestinal symptom and skin disease rates occurred in those nearest the plant. However, significant decreases of some symptoms and diseases also occurred in all three zones. The interpretation of these results is clouded by obtaining the self-reported illness information through a long-recall survey instrument and the inherent variability and inaccuracy of that technique. However, objective measurements, through pathogen isolation from clinical specimens and through serology, were negative. In the Tigard study, the exposure was low, the population at risk was small, and absenteeism is not necessarily indicative of symptoms or illness. The investigators in the Skokie study cautioned against overinterpretation of their negative results because of low exposure and small population.

4. AGRICULTURAL STUDIES

The USEPA has sponsored four agricultural epidemiological studies--three of wastewater spray irrigation and one of anaerobically digested sludge used on cropland. Final reports on two of the wastewater studies and on the sludge study will not be available until later in 1985.

4.1. Israel, Retrospective

A report of a 1976 Israeli retrospective study (not funded by USEPA) indicated that incidence rates for certain infectious diseases (shigellosis, salmonellosis, infectious hepatitis, typhoid fever) were 2 to 4.3 times higher in residents of kibbutzim (agricultural settlements) utilizing wastewater for irrigation (17). The USEPA funded a more thorough study of kibbutzim, examining age-illness distribution, the quality of reporting, crop types and irrigation schedules, distance of fields to residences and dining halls, and length of irrigation season. One group of 13 kibbutzim was in a switch category, i.e., they used effluent irrigation for two consecutive years and then switched to non-effluent sources for another consecutive two years, or vice-versa. A second group of 68 kibbutzim was divided into effluent irrigating, effluent use in fishponds, and non-effluent irrigating categories.

In the switch category kibbutzim, a significant increase was found in the relative risk of enteric disease during effluent irrigation years only in the 0-4 age group (18,19). In the group of 68 kibbutzim, a slight excess of enteric diseases was found in kibbutzim using effluent in fishponds. Although there was no difference in annual enteric disease rates between effluent and non-effluent irrigating kibbutzim, there were increased seasonal rates (May-July), coinciding with the irrigation period, in effluent irrigating kibbutzim. These rates fell below those in the non-effluent irrigating kibbutzim in the fall, thus accounting for the similar annual rates. Significant increases were noted for shigellosis and streptococcal sore throats in effluent irrigating kibbutzim. There was no relationship of the enteric disease rate to source of effluent (own or others), size of the irrigated tract, or distance from residences. These investigators also found that numerous kibbutzim in the previous study were incorrectly classified as to effluent utilization. They suggested that no firm conclusions on the degree of health risk should be based on either that study or this retrospective study because of the poor quality of the data. The cost of this study was about $107,000.

4.2. Israel, Prospective

A prospective study of Israeli kibbutzim residents was begun in late 1979. Thirty kibbutzim with a total population of about 16,000 residents were divided into three major categories: (A) use wastwater for spray irrigation within 600 m of residences; (B) use wastewater or spray irrigation at distances >1000 m from residences or use wastewater in fishponds; (C) use non-effluent water for irrigation or fish-ponds. Subcategories of kibbutzim using local wastewater and that from neighboring towns, and those having no fish-ponds were also included. Environmental monitoring included drinking water and aerosol samples for viruses and bacteria. Illness was monitored through records from the kibbutz health clinics. Serum specimens for viral antibody analyses were obtained from selected residents and from volunteer groups visiting the kibbutzim.

This study is in final stages of analysis. Two preliminary reports (20,21) have addressed antibodies to Legionella and viruses. Infections with Legionella were not found to be associated with wastewater exposure. However, irrigation workers, regardless of the type of water used, had higher prevalence rates to Legionella antibodies. Of eight viral antibodies, excess prevalence was found only for echovirus 4 antibody. The excess was significant in a population exposed to irrigation wastewater derived from nearby towns. These data, and illness data, are undergoing further analyses and should be available in the latter part of 1985. The cost of this study was about $1,272,000.

4.3. Lubbock, TX

A five-year study of a rural population living near a spray irrigation site was begun in 1980. Trickling filter effluent is generated by the City of Lubbock, Texas and is transported by pipeline to farmland (1,500 ha) about 25 km southeast of Lubbock. The average daily flow of 3.7 MGD can be sprayed directly onto the land or stored in reservoirs. Data were collected on approximately 300 residents over a two-year period prior to initiation of spray irrigation and while pipeline construction was in progress. Additional data were collected for another two-year period after irrigation commenced. Environmental samples (wastewater, aerosols and drinking water) were examined for microorganisms throughout the study period. Infection and illness monitoring included health diaries, throat swabs and fecal specimens, and blood specimens for serology (taken every six months). There have been two preliminary reports on the design of the study and on the distribtuion of bacterial infections in the study population (22,23). Klebsiella infections were associated with wastewater exposure but this finding was complicated by an equal association with an area restaurant. This study required funding of almost $2,000,000 and a final report will be available in 1985.

4.4. Columbus, OH

This study was initiated with Ohio State University in Columbus, Ohio in 1977. The overall project was designed to demonstrate sludge management systems for minimizing adverse impacts on the rural community. The health effects portion of the project was a three-year prospective epidemiological study of farm residents in a four-county area of Ohio. Liquid or dewatered anaerobically or aerobically digested sludge was spread at the rate of 2-10 dry metric tons/ha. Sludge was applied to selected fields or parts of fields and the average size of the sludge-applied area ranged from 15-47 ha. The study population consisted of 164 persons (78 families) on 47 farms receiving annual sludge applications. Forty-six control farms had 130 persons in 53 families. Monthly questionnaires were submitted by participants on their health and that of their animals. Annual tuberculin testing was performed and quarterly blood and fecal specimens were obtained. Serological analyses included testing against a series of 21 viral antigens.

No significant differences were observed between sludge farm and control farm residents for respiratory or digestive illnesses or for general symptoms. No participants converted from tuberculin-negative to positive after sludge application, and the frequency of serological conversions to the viral antigens was similar on sludge and control farms. Disease occurrence among domestic animals on sludge and control farms was also similar. The investigators indicated that the low sludge application rates were in accordance with state and federal guidelines, and that caution should be exercised in extrapolating these data to health risks associated with higher application rates and greater exposure. The final report (24) on this project should be available in 1985 and the cost of the health effects portion of the study was about $1,346,000.

5. DISCUSSION

Additional discussion and summaries of most of these studies may be found in the proceedings of symposia on wastewater aerosols (25) and on wastewater disinfection (26). The studies described in the previous chapters do not provide quantitative dose-response information. Exposure was generally categorized by descriptors, e.g., "high" or "low". Objective measures of response, i.e., infection and serology, were used in many

instances, but the value of these is limited by the cooperativeness of the studied population, the impracticality of analyzing for every possible pathogen that may occur in sewage (or the unavailability of acceptable indicators), and by the costs of the analyses. A microbiological or infectious disease hazard associated with sewage treatment and disposal may be inferred because pathogens can be found in sewage, wastewater and sludge. It is the degree of this hazard or risk that is difficult to quantify.

The USEPA has expended somewhat over $8,000,000 in about the last 10 years on epidemiological studies of sewage treatment and disposal. Three of the studies have been retrospective and they ranged in cost from $21,000 to $107,000. The eight prospective studies ranged in cost from $178,000 to $2,000,000 with an average of about $1,000,000. The advantages and disadvantages of retrospective versus prospective studies will not be repeated here as they are fairly well-known and can be found in any fundamental text on epidemiology. While these studies have not been scientifically satisfying in terms of risk assessment, they have been of value in risk management. Risk assessment is the scientific process of determining the quantitative occurrence of adverse effects as a result of exposure to a hazardous situation. Risk management is a decision-making process that takes into consideration risk assessment as well as social, economic and political factors. The results of the occupational studies have suggested that there may be an increased risk of minor illness among sewage treatment employees and that compost workers may experience inflammatory responses as a result of dust exposure or infection with organisms peculiar to the composting process. Generally, the studies of populations living in the vicinity of activated sludge sewage treatment plants have not supported the occurrence of adverse effects in these populations. The results of these studies have been used to respond to citizen concerns regarding the potential health effects of infectious aerosols generated at sewage treatment plants and to make decisions regarding the necessity for covering aeration basins. Complete information is not yet available on the spray irrigation studies, but it has been determined that the extent of the potential hazard is nowhere near the magnitude of that first reported in 1976 (17).

The USEPA does not have any additional sewage treatment and disposal epidemiological studies planned. A possible study of users of distribution and marketing sewage sludges (commercially-available composted or dried sludges) may be conducted in the future if results of a monitoring survey indicate detectable levels of pathogens in these products. In the meantime, efforts are in progress to determine the feasibility for performing quantitative or relative risk assessments through the use of modeling. In this process, information on the occurrence, transport and fate of pathogens in sludges would be intergrated with infectious dose data and exposure calculations to develop risk assessments. The utility of this approach remains to be determined.

DISCLAIMER

The research described in this paper has been reviewed by the U.S. Environmental Protection Agency, Health Effects Research Laboratory and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

REFERENCES

(1) WILLIAMS, F.P. and AKIN, E.W. (1985). Waterborne viral gastroenteritis. Jour. Am. Water Works Assoc. (in press).

(2) BLOCK, J.C. (1983). A review of some problems related to epidemiological studies. In: Biological Health Risks of Sludge Disposal to Land in Cold Climates. Wallis, P.M. and Lehman, D.L. (eds.), pp. 33-46, Univ. of Calgary Press, Alberta, CANADA.

(3) MELNICK, J.L. (1965). Discussion of epidemiology session. In: Transmission of Viruses by the Water Route. Berg, G. (ed.), p. 39, John Wiley and Sons, NY, NY.

(4) CLARK, C.S. et al. (1981). Health risks of human exposure to wastewater. U.S. EPA, Cincinnati, OH, EPA-600/1-81-069.

(5) CLARK, C.S., LINNEMANN, C.C., JR., CLARK, J.G. and GARTSIDE, P.S. (1984). Enteric parasites in workers occupationally exposed to sewage. Jour. Occup. Med., 26:273-275.

(6) CLARK, C.S., BJORNSON, H.S., LINNEMANN, C.C., JR. and GARTSIDE, P.S. (1984). Evaluation of health risks associated with wastewater treatment and sludge composting. U.S. EPA, Cincinnati, OH, EPA-600/1-84-014.

(7) CLARK, C.S. et al. (1985). Serologic survey of rotavirus, Norwalk agent and Prototheca wickerhamii in wastewater workers. Am. Jour. Pub. Hlth., 75:83-85.

(8) DEAN, R.B. (1978). Assessment of disease rates among sewer workers in Copenhagen, Denmark. U.S. EPA, Cincinnati, OH, EPA-600/1-78-007.

(9) LINNEMANN, C.C., JR. et al. (1984). Risk of infection associated with a wastewater spray irrigation system used for farming. Jour. Occup. Med., 26:41-44.

(10) CLARK, C.S., BJORNSON, H.S., LINNEMANN, C.C., JR. and GARTSIDE, P.S. (1984). Evaluation of health risks associated with wastewater treatment and sludge composting. U.S. EPA, Cincinnati, OH, EPA-600/1-84-014.

(11) CLARK, C.S. et al. (1984). Biological health risks associated with the composting of wastewater treatment plant sludge. Jour. Water Poll. Cont. Fed., 56:1269-1276.

(12) FANNIN, K.F. et al. (1978). Health effects of a wastewater treatment system. U.S. EPA, Cincinnati, OH, EPA-600/1-78-062.

(13) JOHNSON, D.E. et al. (1978). Health implications of sewage treatment facilities. U.S. EPA, Cincinnati, OH, EPA-600/1-78-032.

(14) JOHNSON, D.E. et al. (1979). Environmental monitoring of a wastewater treatment plant. U.S. EPA, Cincinnati, OH, EPA-600/1-79-027.

(15) CARNOW, B. et al. (1979). Health effects of aerosols emitted from an activated sludge plant. U.S. EPA, Cincinnati, OH, EPA-600/1-79-019.

(16) SCHEFF, P.A., HOLDEN, J.A. and WADDEN, R.A. (1981). Characterization of air pollutants from an activated sludge process. Jour. Water Poll. Cont. Fed., 53:223-231.

(17) KATZENELSON, E., BUIUM, I. and SHUVAL, H.I. (1976). Risk of communicable disease associated with wastewater irrigation in agricultural settlements. Science, 194:944-946.

(18) FATTAL, B., SHUVAL, H.I., WAX, Y. and DAVIES, A.M. (1981). Study of enteric disease transmission associated with wastewater utilization in agricultural communities in Israel. In: Proceedings, Water Reuse Symposium II, Washington, DC. AWWA Research Foundation, Denver, CO.

(19) SHUVAL, H.I., FATTAL, B. and WAX, Y. (1984). Retrospective epide-

miological study of disease associated with wastewater utilization. U.S. EPA, Cincinnati, OH, EPA-600/1-84-006.

(20) FATTAL, B., MARGALITH, M., SHUVAL, H.I. and MORAG, A. (1984). Community exposure to wastewater and antibody prevalence to several enteroviruses. In: Proceedings, Water Reuse Symposium III, San Diego, CA. AWWA Research Foundation, Denver, CO.

(21) SHUVAL, H., BERCOVIER, H. and FATTAL, B. (1984). Risk of Legionella infection among irrigation workers exposed to aerosols from water and wastewater. In: Proceedings, Water Reuse Symposium III, San Diego, CA. AWWA Research Foundation, Denver, CO.

(22) CAMANN, D.E. and GUENTZEL, M.N. (1984). The distribution of bacterial infections in the Lubbock infection surveillance study of wastewater spray irrigation. In: Proceedings, Water Reuse Symposium III, San Diego, CA. AWWA Research Foundation, Denver, CO.

(23) CAMANN, D.E. et al (1984). Design of the Lubbock infection surveillance study: an investigation of the association of infections with wastewater spray irrigation. Presented at the Annual Meeting, Water Poll. Cont. Fed., Oct., 1984, New Orleans, LA.

(24) BROWN, R.E. (1985). A demonstration of acceptable systems of land disposal of sewage sludge. U.S. EPA, Cincinnati, OH, CS-805189 (in press).

(25) PAHREN, H. and JAKUBOWSKI, W. (eds.). (1980). Wastewater aerosols and disease. U.S. EPA, Cincinnati, OH, EPA-600/9-80-028.

(26) JAKUBOWSKI, W. (1983). Wastewater aerosol health effects studies and the need for disinfection. In: Municipal Wastewater Disinfection, Proceedings of Second National Symposium. Venosa, A.D. and Akin, E.W. (eds.), U.S. EPA, Cincinnati, OH, EPA-600/9-83-009.